

**The Anatomy of *Arenicola assimilis*, Ehlers,
and of a New Variety of the Species, with
some Observations on the Post-larval Stages.**

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With Plates 36 and 37.

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I. Introduction.

IN response to my inquiry regarding the occurrence of *Arenicola* on the shores of New Zealand, Professor Benham kindly sent to me three specimens of this worm from Otago Harbour, and one from the Macquarie Islands.

The specimens were caudate Arenicolidæ resembling *A. marina*, Linn., and *A. clapedii*, Levinsen, in external form. A rapid examination of the grosser anatomical features of one of the Otago specimens seemed to point to its

close affinity with the latter species, for it was at once seen that the New Zealand specimen possessed multiple œsophageal glands and that there were no pouches on the first diaphragm—two features known only in, and considered to be almost diagnostic of, *A. claparedii*. At first, also, only five pairs (the number occurring in *A. claparedii*) of nephridia were seen in the Otago specimen, but finally a much reduced pair was found in the segment anterior to the one bearing the first fully developed nephridia. In the other three specimens sent by Professor Benham there are six pairs of fully developed nephridia, which is evidently the normal condition. The lateral lobes of the prostomium of these specimens were found to be more feebly developed than those of *A. claparedii*. There were therefore two points in which the southern specimens agreed with Levinsen's species, viz. the presence of multiple œsophageal glands and the absence of diaphragmatic pouches; and two features in which they differed, viz. the form of the lateral lobes of the prostomium and the number of nephridia.

On sectioning the anterior end of one of the Otago specimens a pair of large otoecysts was found, each opening to the exterior by a narrow tube. The presence of these well-developed organs, in conjunction with the important differences above mentioned, finally settled that the New Zealand specimens do not belong to the species *A. claparedii*, in which the absence of otoecysts is so characteristic and remarkable a feature.

These specimens agree with *A. marina* in the number, position, and character of their gills, in the number of their nephridia, and in the general anatomy of their otoecysts; but the southern specimens are clearly distinguished from *A. marina* by their multiple œsophageal glands, by the absence in the former of diaphragmatic pouches, and by other less obvious features.

The only other known species to which the New Zealand specimens show any close similarity is *A. assimilis*, Ehlers (1897, pp. 103, 104), of which only the external

characters are briefly described. Ehlers states that this species closely resembles *A. marina* in general external characters, but that in *A. assimilis* there are twenty chætigerous segments and as a rule there are thirteen pairs of gills, the first being situated on the eighth chætigerous annulus, but occasionally only twelve pairs of gills are present. Ehlers also finds that, compared with *A. marina*, the median lobe of the prostomium of *A. assimilis* is proportionately smaller than the lateral ones, and the notopodial setæ somewhat more feebly feathered.

The New Zealand specimens differ from Ehlers' species in the number of chætigerous segments and in the position of the first gill, but unfortunately Ehlers does not mention the nephridia or nephridiopores, the œsophageal glands or the otoeysts,—important diagnostic characters concerning which information was essential before the affinity of the New Zealand specimens with *A. assimilis* could be either accepted or rejected. My thanks are due to Dr. Michaelsen, of the Hamburg Museum, who collected the specimens examined by Ehlers, for kindly sending to me two complete examples of *A. assimilis* from Uschuaia, in Tierra del Fuego, and an incomplete specimen from Punta Arenas, in the Straits of Magellan.

As Ehlers has given only a brief account even of the external characters of his species,¹ I propose to describe the principal features of the three specimens given to me by Dr. Michaelsen before proceeding to consider the New Zealand specimens in detail.

¹ Since writing the above I have received, through the kindness of Professor Ehlers (1901), a copy of his recently published monograph, 'Die Polychæten des magellanischen und chilenischen Strandes,' in which he describes (pp. 177, 178) the structure of the otoeysts of *A. assimilis*, and also states that the alimentary canal, the vascular system, and the nephridia of this species agree, so far as he can ascertain, with those of *A. marina*. This agreement is, however, not quite so close as Ehlers' statement would lead one to expect, since, for example, the œsophageal glands in the latter species are a single pair, while in *A. assimilis* there are several pairs. These points are further discussed below.

II. *Arenicola assimilis*, Ehlers.

The two complete specimens found at low-tide mark at Uschnaia are 105 mm. and 120 mm. long respectively. The specimen from Punta Arenas would have been about 120 mm. long if complete. Their colour in spirit is a fairly uniform yellowish brown, but the tail of one specimen is of a somewhat darker colour. The body is slightly swollen in the anterior region. The animal closely agrees in form with specimens of *A. marina* of the same size.

External Characters.—The prostomium (see fig. 20) is moderately developed; the two lateral lobes are in the form of a **V**, the arms of which embrace the median lobe.¹ The prostomium resembles that of *A. marina* and *A. cristata*, except that the median lobe is proportionately smaller in Ehlers' species. The nuchal organ is similar in its structure and relations to that of *A. marina*. The metastomial grooves indicating the track of the œsophageal connectives are well marked.

There are twenty chætigerous segments, the last thirteen of which are branchiferous; the first gill is thus on the eighth chætigerous annulus. In this character *A. assimilis* differs from all other caudate Arenicolidæ, in which the first gill (except in those abnormal cases in which the first true gill is missing) is on the seventh chætigerous annulus. Of the three specimens in my possession only one has thirteen pairs of fully developed gills; in another the first right gill is very minute; while in the third specimen the first left gill is small, and the last gill on each side is considerably smaller than the preceding one. Ehlers (1897, p. 104) records specimens with only twelve pairs of gills.

The gills of the specimens from Uschnaia are dense bushy structures resembling the dendritic type of gill found in

¹ There is a rough sketch ("d'après Ehlers") of the prostomium of *A. assimilis* in a memoir by Fauvel (1899, p. 178), which, however, does not give an accurate impression of its form, as the two lateral lobes are represented as separate, whereas they are actually united posteriorly to form the V-shaped structure described above.

littoral specimens of *A. marina*. There are in most of them about eight main stems, each 2.5 mm. to 3 mm. long, bearing five or six dichotomously subdivided branches on each side. The gills of the specimen from Punta Arenas are larger and of a somewhat more regular form. The eight or nine stout main stems are about 4 mm. long, and are regularly arranged in radiating fashion; each bears six or seven pairs of branches which divide dichotomously. Although at first sight this gill seems to approach to the pinnate type, the lateral branches are neither so numerous nor so regularly arranged as in pinnate gills, and the gill may be regarded as merely a well-developed example of the dendritic type.

The skin is subdivided into annuli. Between the prostomium and the first chætigerous annulus there are five rings (see fig. 20). The first four of these represent the region found in other species of *Arenicola* which has been shown to be composed of the peristomium (here represented by the first two of these rings) fused with the first body-segment of the post-larva, the setæ in which disappear very early (see figs. 19, 20). The fifth ring is the first annulus of the first chætigerous segment, this segment being composed of three annuli, viz. a chætigerous one and the annulus preceding and following it. The second and third chætigerous segments also consist of three annuli, the middle one bearing the setæ. The fourth and succeeding segments up to the end of the branchial region are composed of five annuli, the fourth of which is chætigerous. The region between any two chætigerous annuli behind the third is therefore subdivided into four rings.

The epidermis of the tail is raised into numerous papillæ. The segmentation of this region is only feebly marked, but it is indicated, especially in the anterior portion of the tail, by the presence of somewhat larger annuli placed at regular intervals, upon which the epidermal papillæ are distinctly larger than those on the intervening annuli. Each of these larger rings is followed by a slight constriction, denoting the presence internally of a septum, best seen in those parts of

the tail which were stretched at the moment of death. The space between two of the larger annuli is subdivided at the anterior end of the tail into two or three rings, but further back into from four to ten. These smaller annuli also bear epidermal papillæ, but in the anterior tail region they are distinctly smaller than the papillæ found on the larger annuli. Proceeding backwards along the tail, the difference in the size of the annuli and of the papillæ they bear may be clearly recognised until the middle of the tail has been passed; then the papillæ become almost equal in size, and near the anus it is impossible to distinguish any difference between those of the various annuli. There are about twenty-eight segments in the tail of each of the complete specimens.

Setæ.—The capillary setæ (figs. 1, 1A) of the notopodium are very similar to those of *A. marina*. They attain a length of 4.3 mm., and on their distal fourth bear small pointed processes, which, as Ehlers (1897, p. 104) remarked, are not so well developed as those of *A. marina*. The processes are usually present on both sides of the seta; they are moderately obvious on one side, but on the other they are very minute, and are borne on the edge of a thin border or lamina. This lamina, which seldom exceeds 6μ in width, extends along the seta for a distance of about one third its length. In some of the setæ the lamina is not denticulate at its margin, and in others is only very faintly so; but it is crossed by fine oblique lines, the intervals between which correspond roughly to the size of the teeth on the dentigerous laminae. From an examination of the setæ of *A. assimilis* and *A. marina*, it seems probable that the lamina at first possesses an entire margin, but later this tends to break up from the edge inwards, thus giving rise to the minute teeth which are usually seen on full-grown setæ. This explanation would account for the fact that in some setæ the margin of the lamina is entire, while in others it bears either exceedingly minute denticulations or the more obvious teeth shown in fig. 1A. These three conditions are occasionally seen at different points along the border of a single seta.

Setæ similar to those above described are present in *A. marina*, and in some examples the lamina is very well marked, e. g. in a specimen of the Laminarian variety the thin border extends for nearly a millimetre along the seta, and attains a width of 20 μ . Similar setæ are present in *A. cristata*, but in *A. claparedii*¹ the lamina is not so well developed, being short and narrow. In *A. ecandata* and *A. grubii* the lamina is also very narrow, seldom exceeding about 3 μ in width.

The neuropodia of *A. assimilis* are easily seen, even in the first segment. They are especially well developed in the branchial region, where each resembles a pair of closely applied tumid lips, between which is the row of crotchets. These (fig. 9) are often curved, and are 0.6 mm. to 0.7 mm. in length, being considerably longer than chaetæ from specimens of *A. marina* of the same size. (The longest crotchets found in a specimen of *A. marina* 125 mm. long are only 0.47 mm. in length.) The rostrum is short and blunt, even in unworn chaetæ. There is a small subrostral enlargement, and about six to nine teeth are present just behind the rostrum.

Musculature.—The musculature calls for little comment; it is similar to that of *A. marina*, except that the oblique muscles are present along the whole animal from the first diaphragm to the end of the tail. They are exceedingly thin bands, somewhat broader in the posterior part of the gill region, but even here seldom exceeding 0.5 mm. in width, and as a rule they are only 0.2 mm to 0.3 mm. wide. There is a dorsal mesentery in the first and second chaetigerous segments supporting the dorsal blood-vessel. The three diaphragms are, as usual, situated at the anterior ends of the first, third, and fourth chaetigerous segments. There are no pouches on the first diaphragm. This condition was considered to be so marked a feature of *A. claparedii* that it was given as one of the diagnostic characters of this species (Gamble and Ashworth, 1900, pp. 533, 541), since all other Arenicolidae whose anatomy is fully investigated possess

¹ See Gamble and Ashworth, 1900, pl. xxiii, fig. 23.

diaphragmatic pouches, and in some species they attain a large size, e.g. in *A. cristata* they may reach a length of 12 mm. Many of the blood-vessels which cross the coelom obliquely to the nephridia and gills are provided with a very obvious connective-tissue strand or band, which gradually increases in size in the posterior segments of the gill region, forming in the last two or three segments of this part of the body an almost complete septum supporting the afferent and efferent branchial vessels. There are well-developed caudal septa.

Alimentary Canal.—The most striking feature of the internal anatomy of *A. assimilis* is the presence of multiple oesophageal pouches. These are placed on the sides of the oesophagus, just behind the third diaphragm. There are in each of two specimens six, and in another eight, pouches on each side. The anterior pair is long—12 mm. in one specimen, 17 mm. in another,—and each of them is usually swollen at or near its anterior free end, having a club-shaped appearance. Their abundant blood-supply is evidenced by the network seen in their walls. In the contracted condition these anterior pouches are digitiform structures with a somewhat moniliform appearance. The smaller posterior glands are from 1 mm. to 4 mm. in length, and are pear-shaped or oval sacs with rather thicker walls. As in other *Arenicolidae*, the cavity of each pouch is partially subdivided by numerous septa produced by infolding of the wall; each septum, therefore, is composed of two lamellæ of glandular epithelium, between which is a cavity filled with blood. The partitions are very obvious in the smaller pouches, and in the larger pouches when in a contracted condition; but when these are fully distended the septa become mere ridges on the inner wall of the pouch. In the presence of multiple oesophageal pouches *A. assimilis* conforms to another of the features hitherto considered to be peculiar to *A. clapedii*, as in all other species of *Arenicola* in which the pouches are known there is only a single pair.¹ In other

¹ Ehlers (1901, p. 177) states that the gut of *A. assimilis* agrees with

respects the alimentary canal resembles that of *A. marina*. The ventral groove, which is well seen in the intestine, may be traced forwards into the stomach to about the level of the eighth or seventh seta.

Vascular System.—The vascular system closely agrees with that of *A. marina* (see Gamble and Ashworth, 1898, pl. ii), except in the fifth and seventh chaetigerous segments. In each of these there is only one pair of vessels, afferent branches of the ventral vessel, passing to the nephridia. The first pair of efferent branchial vessels is situated in the eighth segment; this and the four succeeding pairs open into the subintestinal vessels, while the last eight gills, i. e. those of the thirteenth to twentieth segments, return blood to the dorsal vessel. The body-wall is well supplied with blood-vessels, especially in the anterior region; in sections of the peristomium and first chaetigerous segment there are numerous vessels lying either in the connective tissue or in small coelomic canals (see below) just beneath the epidermis (fig. 22); in sections of some of the posterior segments the vessels are not so abundant.

The heart is of moderate size, and has the usual relations. There is a cardiac body formed by ingrowths, chiefly of the posterior wall of the heart, and this is well developed in one of the specimens 120 mm. long.

Cœlom.—The cœlom is spacious, as in *A. marina*. A remarkable feature noticed at once in sections (fig. 22) of the anterior end of *A. assimilis* is the large number of cœlomic spaces in the body-wall and between the muscles. In this portion of the animal there are exceedingly numerous cœlomic canals lying in the subepidermal tissue of the body-wall, penetrating into the muscle-bands, especially of the buccal musculature, insinuating themselves between the brain-lobes and between the brain and the prostomial epithelium, and often accompanying the blood-vessels which supply the body—that of *A. marina*, but the presence of multiple œsophageal glands in the former while there is only a single pair in the latter species is a point of difference of considerable systematic importance.

wall. In each of these canals the thin lining of coelomic epithelium may be easily recognised, and coelomic corpuscles may also be found in many of them. Similar canals are present in *A. marina* (Gamble and Ashworth, 1898, p. 28), in *A. grubii*, and to a less extent in the other species; but the development of these outgrowths of the coelom reaches its maximum in *A. assimilis*. They probably act as nutritive, and possibly also as excretory and respiratory channels. There are very few coelomic canals in the posterior part of the animal. The coelomic fluid and corpuscles resemble, as far as can be ascertained in preserved specimens, those of *A. marina*.

Nephridia.—There are six pairs of nephridia, the external openings of which are slightly posterior to the dorsal ends of the fourth to the ninth neuropodia. The funnels of the first pair of nephridia lie on the anterior face of the third diaphragm. This condition is found again only in *A. marina*; the first pair of nephridia of other species corresponds in position to the second pair of *A. assimilis* and *A. marina*. The dorsal lip of each nephrostome (fig. 17) bears about twelve to fourteen spatulate or triangular ciliated processes attached by their narrower ends. These are subdivided distally, some of the larger ones into five or six. The edge of the ventral lip of the nephrostome is thrown into folds or frills, so that although it agrees in general shape with the ventral lip of the nephrostome of the *marina* section of the genus, the ventral nephrostomial lip of *A. assimilis* is quite distinguishable by this peculiar character. This frilling is probably not due to contraction on killing, as it is not seen in specimens of *A. marina*, *A. clapedii*, and *A. cristata* which have been killed in a similar manner.

The nephrostome of the first nephridium lies on the anterior face of the third diaphragm, and is directed anteriorly. It is smaller than any of the other nephrostomes, its dorsal lip bears only eight to eleven processes, and the frilling of the edge of the ventral lip is not so well marked.

The first nephridium is usually distinctly smaller than any of the others, a condition frequently noticed in *A. marina*. Although this nephridium possesses a gonidial vessel, no gonad is developed upon it.

Gonads.—The gonads are, as in other species, associated with the nephridia, and are present on all except the first pair. Each gonad is a club-shaped mass of cells about 1.5 mm. long (fig. 17), formed by proliferation of the cells covering the gonidial vessel (Gamble and Ashworth, 1900, p. 521) immediately behind the nephrostome. The formation of ova and spermatozoa follows the same course as in *A. marina*. The ova present in the coelomic fluid of the specimen from Punta Arenas are apparently mature,¹ and have a distinct but thin vitelline membrane (3μ thick). They are not spherical, but somewhat discoidal. The face of the disc is usually oval, and measures 0.19 to 0.20 mm. by 0.15 to 0.16 mm. in diameter. The thickness of the egg is about 0.075 mm. Measurements of a considerable number of well-preserved unshrunk eggs from the coelomic fluid show that the three axes above named are fairly constant in proportion. It will be convenient to correct here a statement in the memoir by Dr. Gamble and myself (1900, p. 527) in which the ova of *A. marina*, *A. claparedii*, and *A. cristata* are described as spherical. This is a mistake, as the ova of all these species are flattened in one plane, like those of *A. assimilis* described above. In *A. marina*² the face of the egg is either circular (usually) and about 0.14 to 0.15 mm. in diameter, or it is oval, with diameters of 0.16 and 0.12 to 0.14 mm., and the third axis of the egg is from 0.08 to 0.09 mm. in length. The ova of *A. claparedii* are usually only slightly oval, the two diameters of the face of the egg being about 0.16 mm. and 0.14 to 0.16 mm. respectively, and the

¹ This specimen was taken in September, 1892.

² The following description and measurements may replace those given on p. 527 in the memoir cited above; they have been drawn either from living or well-preserved ova, most of which have come into my hands since the completion of that memoir.

thickness of the egg 0.07 mm. In *A. cristata* the three axes of ova removed from a ripe female in Naples measure 0.155 mm., 0.145 mm., and 0.07 mm. respectively.¹ The ova of *A. grubii* and *A. ecaudata* are not compressed in this way, or only very slightly so. They are usually ovoid, and ripe ova of the former species are 0.17 mm. long and 0.15 mm. broad and thick. The largest ova of *A. ecaudata* which I have seen have slightly smaller dimensions, but they are probably not quite mature. The ova of *A. grubii* and *A. ecaudata* are distinguished by their stout vitelline membrane, which is 5 to 6 μ thick; while in *A. clapedii*, *A. cristata*, and *A. assimilis* it is 2 to 3 μ , and in *A. marina* only slightly over 1 μ in thickness.

Brain.—The brain of *A. assimilis* conforms to the general plan seen in the *marina* section of the genus. It consists of a pair of anterior lobes placed well forward in the prostomium, a pair of posterior lobes which lie below the nuchal organ, and an intermediate region which connects the anterior and posterior lobes. The anterior lobes are short but very broad; in fact, this is by far the broadest part of the brain; behind these lobes the brain gradually tapers. The brain may be roughly compared in shape to two slightly flattened pears lying side by side with their narrower faces adjacent and fused along the middle third of their length. The broad forwardly directed ends of the pears represent the anterior cerebral lobes, while the tapering ends represent the posterior lobes, which are continuous with two nerve-tracts lying below the epithelium of the nuchal organ. The anterior brain-lobes are separated in front by a coelomic space. Each gives off anteriorly and dorsally a series of nerves to the epithelium of the prostomium. The anterior part of these lobes consists almost entirely of small cells situated in clusters and separated from one another by fibrous tracts and by neuroglial tissue. Further back the delicate neuro-pile which forms the core of these anterior lobes is well seen,

¹ See also Child (1900), p. 592, for further observations on the ova of *A. cristata*.

surrounded by clusters of nerve-cells and neuroglial tissue. Bundles of nerve-fibrils may be traced from the bases of the prostomial epithelial cells into the neuropile (see fig. 23). Larger unipolar ganglion-cells are found immediately outside the neuropile, and particularly on the side nearest the middle line. The œsophageal connectives arise from the anterior lobes at the point where the neuropile reaches its greatest development (fig. 22). The eyes are found on the dorsal side of this part of the brain. There are four or five on each of the anterior lobes. A little further back large pyriform ganglion-cells become more numerous, and especially on the inner side of the two anterior lobes just before they unite in the middle line and for some distance after their union (see fig. 23). Passing backwards along this region, it is seen that the ganglion-cells become more restricted to the dorsal and lateral faces of the brain, the middle and ventral parts being composed largely of neuropile, in which also neuroglial cells and fibrillæ may be recognised. The ganglion-cells of this region are more intimately associated with the median part of the prostomium.

The posterior brain-lobes are small and tapering, and gradually merge into two nerve-tracts which lie on the inner side of the nuchal organ just below the sensory epithelium. The brain of the specimen 120 mm. long is 0.65 mm. in length, 1 mm. broad across the anterior lobes, and about 0.4 mm. deep in this region. It is most nearly like the brain of *A. marina*, but is wider anteriorly. (The brain of a specimen of *A. marina* 120 mm. long is about 0.7 mm. wide.)

Æsophageal Connectives.—The œsophageal connectives arise from the lateral region of the broadest part of the anterior cerebral lobes, i. e. just in front of their point of union. Each is a stout fibrous cord with numerous cells on its outer face, which, in the first part of its course, lies about a millimetre below the epidermis, and is slung up in a muscle sheet, which is attached to the subepidermal musculature by numerous muscle-strands (fig. 22). It is only in the ventro-lateral region that the connectives approach the

body-wall and finally come to lie upon the layer of circular muscles. The connectives, the course of which is indicated externally by the metastomial grooves, unite in the hinder portion of the third annulus (cf. fig. 19). Each gives off numerous branches to the epidermis of the region through which it passes; in fact, the nerve-supply to the skin and following segment is enormous—nerves pass into the raised areas upon the skin and repeatedly branch, their terminations lying in close contact with the bases of the epidermal cells (fig. 22). In addition to one or two nerves derived from each connective, the skin of the region immediately below the prostomium receives two moderately stout nerves which arise from the ventral portion of each anterior cerebral lobe close to the point of origin of the connective. These nerves run on to the roof and sides of the mouth, and their branches may be traced a considerable distance along the pharynx. They are apparently more numerous on the dorsal than on the ventral region of the pharynx. In many sections the nerves may be seen sending branches along the axes of the buccal papillæ (fig. 22). The connective gives off a very short but stout nerve to the otocyst. Ganglion-cells are present in moderate number around the point of origin of this nerve. The nerve comes into contact with the otocyst at the point where the tube leads off to the exterior, and is intimately related to both structures. It provides the otocyst with a sheath of nervous elements, which lies just below the sensory epithelium, and also sends a small nervous sheath along the tube.

Nerve-cord.—The nerve-cord is situated within the layer of circular muscles. The right and left fibrous portions are separated by a median vertical sheet of neuroglia. The ganglion-cells are distributed along the whole length of the cord, and are not aggregated into ganglia. They are numerous, unipolar, pyriform, usually quite small cells with deeply staining nuclei, and most of them are situated in the ventro-lateral regions of the cord; but some few larger ones measuring from $15\ \mu$ to $30\ \mu$ in length, and having vesicular

nuclei, are found rather nearer the middle line in many of the sections examined. The process of each cell is directed dorsally into the lateral portion of the fibrous mass. The spinal nerves arise in the same manner and position as in other Arenicolidae (Gamble and Ashworth, 1900, pp. 482, 483). Giant-fibres to the number of two or three are seen in sections of the branchial region and tail. The giant-cells are regularly arranged, being situated close to the posterior border of each segment. In eight of the nine segments examined there is only one giant-cell per segment, but in the other segment two cells are present near together. The giant-cells are placed in the extreme lateral regions of the cord, and in the first piece of cord which was sectioned they are situated alternately on the right and left sides, i.e. in the seventeenth to twentieth chaetigerous segments, and in the first tail segment of this specimen they are situated respectively R, L, R, L, R (see fig. 12). In sections of the same specimen taken further forwards (tenth to thirteenth segments) this curiously regular arrangement was not found, the cells present in these segments being situated respectively L, L, R R (two cells are present in this somite), R. The average size of the cells is 0.065 mm. long and 0.05 mm. broad and deep. Each cell is pyriform, surrounded by a fibrillated sheath, and sends out usually only one process, which passes at once into the fibrous portion of the cord towards the lateral giant-fibre. The protoplasm of one cell, however, is drawn out dorsally into five processes, one of which is much thicker than the others, and may be easily traced into the mid-dorsal region of the fibrous part of the cord. The slender processes are traceable only a very short distance, being lost either between the small ganglion-cells or immediately on entering the fibrous part of the cord. There is in most of the giant-cells a more deeply staining area in the protoplasm close to the nucleus, due to the presence of chromophilous granules. This probably corresponds to the similar but better marked centrosphere seen in *A. grubii* (Gamble and Ashworth, 1900, pp. 487, 488, and fig. 76).

Sense Organs.—The eyes, of which there are four or five on each side of the prostomium, are similar to those of other Arenicolidae (Gamble and Ashworth, 1900, pp. 506, 507). They are situated either among the small nerve-cells on the dorsal surface of the anterior cerebral lobes just in front of their point of union, or in the epidermis immediately dorsal to this region. Each eye is composed of a cup-shaped mass (6 to 12 μ in diameter) of reddish-brown pigment spherules grasping the base of a spherical or ovoid lens.

The otocysts¹ are remarkable for their large size. They are oval sacs whose three internal diameters are 0.37, 0.36, and 0.25 mm. respectively. Their size may be better appreciated after comparison with that of the otocysts of other species (see figs. 13, 16). The largest otocysts seen while examining four large specimens of *A. marina* for this purpose were found in one about 180 mm. long, where they measure 0.07, 0.16, and 0.17 mm. along each of their three internal diameters; while in a specimen 250 mm. long the corresponding measurements are 0.13, 0.12, and 0.15 mm. (fig. 16). The nearly spherical otocysts of full-grown specimens of *A. cristata* (300 mm. long), *A. grubii* (180 mm.), and *A. ecandata* (180 mm.) have a mean internal diameter of 0.17 to 0.18 mm., 0.16 to 0.17 mm., and 0.12 to 0.13 mm. respectively. From these figures it will be seen that the otocysts of *A. assimilis* are much larger than those of any other species. Each opens to the exterior by a narrow curved tube. The external opening is very minute, and at the bottom of a groove situated immediately in front and to the outer side of the lateral portion of the nuchal organ (fig. 22).

¹ Ehlers (1901, pp. 177, 178) has recently described these organs and their numerous spherical otoliths, consisting of a concentrically layered, evidently secreted, material. These vary in size from 0.003 to 0.03 mm. The small ones are compared to those of *A. clapedii* (the author really means *A. grubii*). The larger otoliths are often irregular, and in a few a central foreign body may be observed. The opening of the tube into the cyst is very small, and Ehlers thinks this is correlated with the character of the otoliths. He also states that the otocyst is apparently larger and its external opening nearer the brain than in *A. marina*.

The opening is close to the point of origin of the œsophageal connective, i. e. at the dorsal end of the metastomial groove, so that it is more dorsally situated than the corresponding opening in *A. marina*. The lumen of the tube is small, and in two of the four examined is almost obliterated along part of its length by approximation of the walls. In three of the tubes there are fine particles of foreign matter at one or more points. The otocyst and tube are lined with a cuticle about $3\ \mu$ in thickness. The epithelial wall of the otocyst is comparatively thin (30 to $40\ \mu$). The sense cells are not easily distinguishable, at first sight, from the supporting cells, but in one series of sections they may be distinguished by the presence of neuro-fibrillæ in the former. Each sense cell is seen to be traversed by a single fine fibril, which terminates immediately below the cuticle. These cells and fibrillæ are especially abundant in the wall of the otocyst near the entrance of the tube, and they are also present in the adjacent part of the tube. Below the epithelium is the nervous sheath, among the fibres of which occur scattered fusiform or stellate cells. The nerve-supply to the otocyst is derived from the œsophageal connectives (see above, p. 750). The otocyst contains the coagulated remains of the fluid with which it was filled in life. Among this coagulum are numerous minute spherical deeply staining granules, which are probably secreted by some of the cells in the wall of the otocyst (fig. 13). There are about forty or fifty otoliths in each otocyst; they are usually spherical, but a few are oval, and some are irregular, but have a rounded outline. They nearly all show concentric markings indicating the method of their formation by deposition of layer upon layer of a secretion produced by cells in the wall of the otocyst. The largest otoliths are $35\ \mu$ to $45\ \mu$ in diameter. In the centre of a few of them there is a minute refringent body, evidently of foreign origin, forming the nucleus around which the secreted matter has been deposited. Besides the contents already named, there are in the otocyst several deeply staining bodies varying in size from the minute granules

present in the coagulum to spherical, oval, or elongate masses $10\ \mu$ in diameter, which are either free or adhering to the surface of one of the otoliths. Their appearance suggests that they are composed of a substance similar to that of which the otoliths are formed, although the latter are usually much more lightly stained (fig. 13).

The nuchal organ of *A. assimilis* resembles that of *A. marina* in its main features. The epithelium of the organ is composed of exceedingly slender columnar cells; some of these—the sense cells—are $70\ \mu$ to $80\ \mu$ long, and only about $2\ \mu$ wide, and have deeply staining nuclei. The intervening supporting cells are a little stouter, and their nuclei stain less deeply. Many of these cells are ciliated, and some are glandular. Beneath the epithelium there is a layer of nerve elements in connection with the posterior brain-lobes. From this layer neuro-fibrillæ may be traced into and through the entire length of many of the sensory cells.

Similar fibrils may be seen in some of the epidermal cells of the general body surface, and of the papillæ of the proboscis.

III. Specimens of *Arenicoia* from New Zealand.

Three of these were collected in Otago Harbour, and are respectively 136, 126, and 90 mm. long. Another specimen from the Macquarie Islands is 217 mm. long. The Otago specimens are of a light brown colour, the two larger ones being darker in the anterior gill region, and the Macquarie specimen is dark brown throughout its length.

External Characters.—The prostomium (fig. 20), the nuchal organ, and the metastomial grooves agree in form and relations with those of *A. assimilis*. There are nineteen chaetigerous segments, of which the last thirteen usually bear gills. The first gill is thus situated on the seventh segment, as in *A. marina*, *A. clapedii*, and *A. cristata*. The gills of the two larger Otago specimens are all fully developed, but in the smallest specimen the last right gill is smaller

than any of the others, and its fellow on the left side is represented by a single filament about half a millimetre in length and bifid at the tip. In the Macquarie specimen there are only twelve pairs of gills, the first being well developed and situated on the eighth chætigerous annulus. The true first gill¹ is totally absent, a condition frequently met with in *A. marina*. The gills of the Otago specimens are of the pinnate type, and are beautifully regular in arrangement. Each consists of fourteen to sixteen main stems, usually 3.5–4 mm. long (but in several cases reaching 6 mm.), which radiate from the base of the notopodium, and are connected near their bases by a web-like membrane. Each stem bears eleven to eighteen pairs of pinnæ, which are either opposite or almost alternate in arrangement and usually divide dichotomously. These gills are remarkable for the enormous size of the afferent and efferent blood-vessels, best seen in the main stems and in the larger pinnæ. They closely resemble the gills of the Laminarian variety of *A. marina* figured by Gamble and Ashworth (1898, pl. i, fig. 2), except that the webbing at the base is more pronounced in the southern specimens. The gills of the Macquarie specimen are of a different type. They have only seven or eight main trunks 3.5–5.5 mm. long, each bearing six or eight pinnæ on each side, and these are less regularly arranged than in the Otago specimens. There is no connecting membrane at the bases of the main trunks. These gills resemble in form, but are larger than, those of the *Uschuaia* specimens of *A. assimilis* (see p. 740).

The annulation of the skin is exactly like that of *A. assimilis* (see p. 741).

Setæ.—The notopodial setæ (figs. 2, 2A) taper more abruptly at the tip than those of *A. assimilis*. Those of the Otago specimen are 4 mm. long. The usual pointed barbs or processes are present on one side of the shaft of the seta, while on the other is a well-marked lamina, which in most setæ is 12 μ , and in some is 15 μ broad. The

The pair of efferent vessels of this segment is also completely suppressed.

margin of the lamina is in many cases entire, but in some is very finely dentate. The setæ of the Macquarie specimen are about 5 mm. long, and the lamina is much narrower, being only about $6\ \mu$ in width.

The neuropodia are well developed; the crotchets show an interesting feature. On examining the post-rostral region (fig. 7), there are seen to be about five to seven teeth—that is, five, six, or seven teeth are in focus at the same time as the rostrum, and lie approximately in the same plane. On focusing slightly above or below this level, there comes into view a number of teeth situated on the sides of the rostrum, so that the latter projects from the centre of a series of teeth arranged around its base (fig. 8). The small subrostral process marks the position of the base of the lowest tooth of the series. Only those chætæ which have not been much worn show these lateral teeth.¹ The rostrum is slightly longer and more pointed, and the enlargement near the middle of the shaft better marked than in Ehlers' species. Many of the crotchets are strongly curved. They vary in length in the Otago specimens from 0.66 mm. to 0.8 mm., and in the Macquarie specimen they reach a length of 0.86 mm. The last-named chætæ are stouter, the rostrum more rounded at the tip, and more nearly in line with the shaft, and the teeth are more feebly marked; these characters are due to the greater age of the specimen from which the chætæ were taken.

Musculature.—The musculature is very similar to that of *A. assimilis*, except that the muscles in the region of the first diaphragm are more slender in the Otago specimens. Oblique muscles are present along the body from the first diaphragm to the end of the tail. There are no pouches on the first diaphragm.

Alimentary Canal.—The alimentary canal agrees most minutely with that of *A. assimilis*. Multiple œsophageal

¹ They are very well seen in the crotchets of post-larval stages (see fig. 10). A similar series of teeth is present around the base of the rostrum of the chætæ of other Arenieolidæ, but they are not so easily distinguished as in the specimens above described.

ponches, to the number of seven on each side, are present in the three specimens examined. The anterior pair is long and filiform or club-shaped, measuring in one case 15 mm., and in the other two specimens 24 mm. in length. The other pouches are pyriform or ovoid, and 3 to 5 mm. long.

Vascular System.—The vascular system agrees closely with that of *A. marina*,¹ and only differs from that of *A. assimilis* in the position of the first efferent branchial vessel. The first six efferent branchial vessels open into the subintestinal vessels, and the last seven into the dorsal vessel. The heart of the specimen 126 mm. long contains a moderately developed heart-body.

Nephridia.—There are six pairs of nephridia, opening, as in *A. marina* and *A. assimilis*, on the fourth to the ninth segments. In the three specimens examined the first pair is smaller than any of the others, and one of the nephridia is considerably reduced, no funnel being visible. The funnels of the first nephridia lie on the anterior face of the first diaphragm. Their dorsal lips bear about six broad, but usually undivided, ciliated processes, and their ventral lips, though small, are thrown into several of the peculiar folds or frills as described above (p. 746) in the nephrostomes of *A. assimilis*. The funnels of the other nephridia are larger; their dorsal lips bear about sixteen spatulate processes, most of which are subdivided terminally into five or six, and their ventral lips are thrown into some twenty or more folds. The vesicles of the nephridia had been recently greatly distended but are now almost empty.

Gonads.—The gonads are small and occur in the usual position. None are present on the first pair of nephridia. It is probable that the breeding season of these specimens was practically over at the time of their capture (September, 1899). It is evident that the nephridial vesicles had been recently subjected to great distension, and this was probably due to the accumulation therein of genital products. Similar

¹ Except that in the Otago specimens there is in connection with the third nephridium only one blood-vessel, viz. an afferent branch of the ventral vessel.

distension of the vesicles occurs during the breeding season in *A. marina*, *A. grubii*, and *A. caudata* (Gamble and Ashworth, 1898, pl. iii, fig. 15, and 1900, pl. xxvi, fig. 47). On staining and clearing the nephridia the vesicles are found to still contain either a few large ova or masses of spermatids. The ova are of the same somewhat flattened shape as those of *A. assimilis*. Their three axes measure 0.195 to 0.20 m.m., 0.16 to 0.175 mm., and 0.075 mm. respectively. (For the measurements of the ova of other species see p. 747.)

Central Nervous System.—The brain resembles that of the *Uschnaia* specimens, except that the anterior lobes are much broader. In the specimen 126 mm. long the brain is about 0.7 mm. long, and is broadest across the anterior lobes at the point of origin of the œsophageal connectives. The breadth of the brain at this point is 1.5 mm. and its depth 0.4 mm. After the fusion of the two anterior lobes the brain rapidly narrows, so that its middle region is only about 0.7 mm. broad. The structure of the anterior lobes is exactly as described for *A. assimilis* on pp. 748, 749. Near their point of union larger ganglion-cells occur near the middle line, gradually increasing in number posteriorly and being found over the whole dorsal face of the neuropile of the mid-brain. In the posterior part of this region there are a few groups of pyriform, fusiform, or pyramidal ganglion-cells, the stout processes (usually only one to each cell) of which are united into a number of bundles. These processes pass downwards into the ventral portion of the neuropile, where they branch freely (see fig. 23). Similar ganglion-cells extend some distance into the posterior brain lobes. In other respects the brain of these specimens conforms to the description given on pp. 748, 749.

The œsophageal connectives arise, as usual, from the posterior part of the anterior cerebral lobes. They lie immediately below the epidermis of the metastomial groove, and give off numerous nerves to the skin and buccal musculature. There is a slight swelling on the connective at the origin of the nerve to the otocyst.

The situation and structure of the nerve-cord agree with the description given on p. 750. Sections taken in the mid-branchial region show one, two, or sometimes three giant-fibres. Serial sections of three segments (fig. 11) of this part show that in the first and last segments there are two giant-cells, and in the middle one only one cell. When two cells are present they lie, as in *A. grubii*, one behind the other, the anterior one being only a little distance posterior to the parapodium. The cells are laterally situated, pyriform in shape, and their single process is directed into the adjacent fibrous portion of the cord.

Sense Organs.—The nuchal organ and the reddish-brown eyes have the usual structure and position.

The otocysts are somewhat smaller and lie more laterally than in *A. assimilis*. They are almost spherical sacs (fig. 15) about 0.21 mm. in diameter, which communicate with the exterior by a tube, whose external aperture occupies a similar position to the corresponding opening in *A. marina*. It is situated near the metastomial groove, but further from the brain than in *A. assimilis*. The otoliths are of purely external origin. They consist of numerous irregular bodies (quartz-grains, fragments of spicules, etc.), without any of the chitinoid covering which is usually associated with the otoliths of *A. marina*, and which forms the major portion of each otolith of *A. assimilis*. There are in each otocyst from twenty to fifty moderately large bodies, the largest being 55 μ long and 27 μ broad, and also a quantity of finer débris of similar origin and character. The lumen of the tube is slit-like, and about halfway down one of the tubes there are at two points large foreign bodies. In the structure of its wall the otocyst agrees with that of *A. assimilis* (p. 753).

IV. Systematic Position of *Arenicola assimilis* and of the Specimens from New Zealand.

Arenicola assimilis is clearly distinguished from all other species by the following characters:—(a) externally, by its twenty chaetigerous segments and the presence of the first gill on the eighth segment; and (b) internally, by the possession of six pairs of nephridia opening on the fourth to the ninth segments, by the presence of numerous œsophageal glands and of large otocysts opening to the exterior, and by the absence of the pouches on the first diaphragm.

This species obviously falls within the caudate section of the genus *Arenicola*. It has practically no points in common with *A. cristata* except those of generic value; the two species differ in every one of the characters named above. Ehlers' species has some points of resemblance to *A. claparedii*; in fact, the two most characteristic features of the latter species are found in *A. assimilis*, viz. the multiple œsophageal glands and the absence of diaphragmatic pouches. But these two species are clearly distinguished by the differences in the number of segments, the position of the first gill, the number of nephridia, and the presence in *A. assimilis* of large otocysts, such organs being absent in *A. claparedii*.

The structures hitherto believed to be diagnostic of *A. marina* are also found in Ehlers' species, viz. six pairs of nephridia opening on segments 4 to 9, and a pair of open otocysts. These two species may be easily differentiated by an inspection of the number of segments, the position of the first gill, the œsophageal glands, and the first diaphragm (to ascertain the presence or absence of pouches).

So that, although related in some degree to *A. marina* and *A. claparedii*, *A. assimilis* is quite distinct from either, and may be easily determined by reference to the six characters given above.

The determination of the systematic position of the New

Zealand specimens is a matter of considerable difficulty. In the number of chætigerous segments and position of first gill they resemble *A. marina* and *A. claparedii*, but the prostomium is more nearly like that of the former. Internally there are four characters, two of which are in agreement with those of *A. marina* and in contrast to those of *A. claparedii*, and two are vice versâ—(1) the number and position of the nephridia and the presence of open otocysts, and (2) the presence of multiple œsophageal glands and the absence of pouches on the first diaphragm. The absence of otocysts in *A. claparedii* is so remarkable and characteristic a feature that their presence in the Otago specimens, taken in conjunction with the important differences in the number of nephridia and the form of the prostomium, is sufficient to exclude the southern specimens from Levinsen's species. While their relationship with *A. marina* rests on a stronger basis, the internal differences are too important to be passed over, and one must look elsewhere for a nearer ally.

Throughout the description of the anatomy of the New Zealand specimens it is striking how frequently a perfect agreement occurs between them and *A. assimilis*. Their prostomia are practically identical, and they further agree in almost every internal character—the number and position of their nephridia, their œsophageal glands, the absence of pouches on the first diaphragm, the form and structure of the brain, the large size of their open otocysts and of their ova. The only differences are externally in the number of segments and the position of the first gill, and internally in the vessels of the seventh segment and in the nature of the otoliths. It is a question whether these differences are of sufficient importance to justify the separation of the New Zealand specimens as a distinct species.

The form of the otoliths is certainly very different. In *A. assimilis* they are rounded, and consist almost entirely of a substance secreted by the cells in the wall of the otocyst, while in the New Zealand specimens they are irregular foreign bodies (figs. 749, 751). Ehlers has re-

marked (1901, p. 178) on the small size of the opening from the tube into the otocyst in *A. assimilis*, and considered that this was connected with the form of the otoliths. I had previously arrived at the conclusion that their shape was due to the closure of the lumen of the tube, and had examined a number of otocysts of *A. marina* to obtain further evidence on this question. The anterior ends of nine specimens of the latter species have been sectioned, and show considerable differences in the character of their otoliths. Six of the specimens are comparatively young (from about 17 to 65 mm. in length), and their otoliths are irregular foreign bodies such as quartz-grains, portions of spicules, frustules of diatoms, etc., which are almost naked, i. e. they have either no secreted covering, or else it is a mere film, the presence of which is indicated by its staining with hæmatoxylin. Of the remaining three older specimens, one, which is about 170 mm. long, has irregular otoliths like those described above, but in the other two, which are about 130 and 250 mm. long respectively, the otoliths have quite a different appearance. They were at first irregular, but the original particles have been covered by layer upon layer of secreted substance, and the resultant otoliths have rounded outlines (see fig. 16). The tubes of these two pairs of otocysts are found to be practically closed along almost their whole length, either by apposition of the walls or by the blocking of the lumen by a granular substance secreted by the gland-cells in the wall of the tube. In each case the walls of the tube are so closely apposed that the lumen along the greater part of its length is reduced to a slit not more than 3 or 4 μ across, and even this space is occupied by a thin band of the secreted substance mentioned above, thus effectually closing the passage. The variation in the nature of the otoliths is probably dependent on the condition of the tube. At any rate, it is interesting to note that in the large specimen (170 mm. long) with irregular otoliths mentioned above, the lumen of the tube, as seen in section, is a fair-sized slit, and is not encroached upon to any extent by secretion

such as blocks the tubes in the specimens with rounded otoliths. It is also worthy of note that in the other species of *Arenicola* (*cristata*, *grubii*, *ecaudata*) which have rounded or spherical otoliths, formed largely of secreted matter, the otocyst is a closed vesicle. It seems probable, therefore, that the presence or absence of an open passage connecting the otocyst to the exterior has considerable influence upon the character of the otoliths, which varies even in different specimens of the same species. The fact that the otoliths of *A. assimilis* are rounded, while those of the New Zealand specimens are irregular, is not of fundamental importance; it probably indicates that in the former the tube leading from the otocyst to the exterior very soon became blocked, and the otoliths are therefore largely composed of material deposited around the small particles which had gained access to the otocyst before the closure of its tube. The otocysts of *A. assimilis* and of the New Zealand specimens agree in the most important character, namely, that each possesses a tube leading to the exterior; and the modification which takes place in the former, causing a difference in the nature and shape of the otoliths, may be regarded as of secondary importance, since a similar, though not so marked a difference, may be observed within the limits of a single species (*A. marina*). For further remarks on this subject see p. 771.

While the number of chaetigerous segments in the ecaudate *Arenicolidae* varies greatly (from about twenty-four to forty in *A. grubii*, and thirty-five to fifty-six in *A. ecaudata*), it is peculiarly constant in three of the caudate species, there being invariably nineteen in *A. marina* and *A. claparedii*, and seventeen in *A. cristata*. In most American specimens of the last-named species there is, however, an extension into the tail of structures which are usually associated only with parapodia. Small gills and cirriform processes occur upon the first two or three tail segments of one specimen examined (Gamble and Ashworth, 1900, p. 442, figs. 31, 32), and similar processes are commonly present on American specimens, but

have never been recorded in any Neapolitan specimen of this species.

With this example in mind it is not difficult to believe that, in a species probably widely ranging over the enormous coast-line of the South Atlantic and Pacific Oceans, some specimens may have become modified in the direction above indicated, so that finally a condition was reached in which some members of the species possess nineteen and others twenty segments. If we suppose that an additional parapodium and gill have been produced, the only alteration necessary to bring such a form into line with *A. assimilis* would be the loss of a gill at the anterior end of the series. The reduction and absence of the first gill are so frequently observed in *A. marina* (and to a less extent in almost all other species) that the reduction and eventual loss of the first gill of the hypothetical form are quite conceivable.

In my opinion the possession of an extra chaetigerous segment, though striking, is scarcely a sufficiently important character to form by itself a test of specific value, and to be used as the sole means of distinguishing two otherwise identical forms. It seems preferable to regard the New Zealand specimens as forming a variety of the species *A. assimilis*, to which the name *affinis* may be given indicating its close connection with and resemblance to the type.

V. Post-larval Stages of *Arenicola* from the Falkland Islands.

After finding multiple oesophageal pouches in adult specimens of *Arenicola assimilis*, it occurred to me that I might be in error in the determination of the species of certain post-larval *Arenicolidae* from the Falkland Islands, and a re-examination of them became necessary. The specimens were preserved in, and handed to me in, formalin, and I examined them in that fluid two years ago. On finding multiple oesophageal glands I had little hesitation in referring them to the species *A. clapedii*, because at that

time the occurrence of several pairs of œsophageal cæca was known only in this species, and, indeed, was considered to be one of its most characteristic features. At the same time I looked for the otocysts, but did not succeed in finding them.¹ They would have been moderately easy to see in post-larval stages of *A. marina* of the same size, and finding no similar structures in my post-larvæ I therefore concluded (wrongly, as it now appears) that otocysts were absent. With these two features in mind, but relying especially on the very obvious presence of several œsophageal pouches, I identified the specimens as post-larval stages of *A. claparedii*, and as such they were recorded by Miss Pratt (1901, p. 12). The fact that these specimens had been obtained in the region in which *A. assimilis* is found had not escaped my notice, but as Ehlers' account (1897, pp. 103, 104) stated that his species closely resembled *A. marina*, it was naturally concluded that the presence of multiple œsophageal glands might still be regarded as a diagnostic character of *A. claparedii*.

These post-larvæ have now been carefully re-examined, both entire and in sections, with the result that my previous determination is found to be wrong; they are the young stages of *A. assimilis*, var. *affinis*.

The three specimens were found on the surface of the sea near the Falkland Islands, by Mr. R. Vallentin, of New Quay, and were handed over to me by Miss Pratt, of Owens College, Manchester, who was working over Mr. Vallentin's collection of Polychætes.

The specimens are 7·6, 8·7, and 11·1 mm. long respectively. The largest specimen is provided with a transparent gelatinous envelope about 1 mm. in diameter, which covers the animal, except for a distance of a little over a millimetre at each end. In general aspect these post-larvæ resemble those of *A. marina*.

¹ The nephridiopores were also examined, but on account of their minute size it was impossible to make certain of their presence or absence on the critical segment (the fourth), and therefore their number could not be definitely ascertained.

There are sparsely scattered greenish-brown pigment cells in the epidermis.

The conical prostomium bears from two to four small brownish-red eyes on each side (fig. 18). It is followed by a region divided into two by a faint groove (figs. 18, 19). The anterior portion of this region is the true peristomial segment, and in the largest specimen is itself encircled by a groove, which subdivides it into two annuli. The posterior part of the region above named corresponds to the segment bearing the minute vestigial seta in the post-larvæ of *A. marina* (Benham, 1893, p. 49). There is no trace of setæ in this segment in the post-larvæ now under consideration. In adults (see fig. 20) the region between the prostomium and first chætigerous segment is divided into four rings (see p. 741), in the third of which the œsophageal connectives unite. By comparison with these post-larvæ, it is seen that the first two rings of the adult belong to the prostomium and the other two to the first true body-somite, which, in *Arenicola*, has lost its setæ and has become fused with the peristomium.

There are nineteen chætigerous segments, in each of which crotchets and setæ may be clearly distinguished. There are two kinds of setæ present in the notopodia. The more numerous and longer ones are very similar to those of the adult (fig. 3). They are about 0.3 mm. long, and bear a lamina along about half their length. The shorter setæ, about 0.25 mm. long, are obviously laminate for a short distance on both sides (figs. 4, 5). They are almost lanceolate in shape, and drawn out into long, slender tips. Only one of these setæ is usually present in each notopodium, in which there are two to four setæ altogether. There is a tendency, more marked in the lanceolate setæ, for the lamina to break up, from the edge inwards, into fine, pointed teeth (figs. 4, 6).

The crotchets are 0.07 to 0.08 mm. long, and are distinguished by the presence of a thickening, forming an encircling ridge upon the shaft of the chæta (fig. 10). This ridge lies just below the level of the epidermis. As described on p. 756,

the teeth are not confined to the region immediately behind the rostrum, as on careful focussing they may be found also on the sides of the rostrum. There is really, therefore, a circular series of teeth from the centre of which the rostrum projects, and the subrostral process is the lowest of this series. Fig. 10 A shows the appearance of the crotchet when the rostrum is in sharp focus; in fig. 10 B the other teeth seen on focussing slightly upwards are added.

Each of the posterior tail segments is divided by slight constrictions so as to present a tri-annulate appearance. The anal segment is somewhat swollen, and the lips of the anus are crenate.

There are no gills present in any of the specimens. The blood is light red in colour (in formalin).

After staining and clearing the specimens the alimentary canal could be well seen (fig. 18). The muscular pharynx leads into the thick-walled œsophagus, which bears on the dorsal surface of its posterior portion the œsophageal glands, of which there are from six to eight visible on each side; the anterior one is the largest. Just behind this point the œsophagus is slightly constricted, and the two hearts lie on its lateral walls. The stomach is a wider tube, and upon its walls may be clearly seen the vessels of the gastric plexus bounding the chlorogogenous areas. The intestine, like that of the adult, is thrown into concertina-like folds.

Sections show that the anterior part of the œsophagus is ciliated, and that the stomach is lined by columnar cells, many of which contain a vacuole near the end which adjoins the digestive cavity.

In sections of the anterior ends of the two smaller specimens the otocysts are not easily found; they are much less clearly differentiated at this stage than those of corresponding post-larval stages of *A. marina* and *A. ecaudata*. They are seen to be two small pits in the epidermis, the lips of which are approximated so as to form a very short tube (fig. 21). Each otocyst is somewhat triangular in section; its apex is directed laterally and leads to the external open-

ing. There are in each otocyst from four to six foreign bodies (otoliths), all of which are apparently quartz-grains except two; these are obviously fragments of spicules. The otocysts of the specimen 11.1 mm. long are faintly visible in a stained preparation of the whole animal cleared in thick cedar-wood oil. They are about 40μ by 25μ in internal diameter (fig. 18).

The nuchal organ is easily recognisable; its cells are richly ciliated (figs. 18, 21).

Neither giant-cells nor giant-fibres can be identified in the nerve-cord at this stage.

Six pairs of nephridia may be traced in sections. The first nephridium is small, and its anterior end runs forward and pierces the third diaphragm. On the sixth nephridium the gonidial vessel has a covering of cells which have large spherical nuclei. This is the gonad, and it may also be distinguished, though not so clearly, on the fourth and fifth nephridia.

The above-described post-larval stages are evidently not young specimens of *A. clapedii*, as is shown by the presence of otocysts and six pairs of nephridia. They are the young stages of the variety of *A. assimilis*.

Ehlers (1897, p. 104) has recorded from *Uschuaia* a similar gill-less specimen about 6.5 mm. long, which bears nineteen chaetigerous segments. This post-larval stage was found among the "roots" of seaweeds (*Tangwürceln*), and had probably recently settled down to its littoral habitat.

VI. Adult Specimens of *Arenicola* from the Falkland Islands.

When the foregoing account was ready for press I received, through the kindness of Mr. R. Vallentin, of New Quay, Cornwall, five adult specimens of *Arenicola* from the Falkland Islands, and have thus been able to confirm some of the observations described in the former part of this paper.

The specimens were dug from the sand in Whale Sound, Stanley Harbour, during the early months of this year (1902). They are respectively 187, 185, 135, 128, and 121 mm. long. Each has nineteen chaetigerous segments, the seventh of which bears the first and invariably small pair of gills.¹ The other external characters, e. g. the prostomium, annulation, etc., agree exactly with those of the Otago specimens, while internally the agreement is scarcely less perfect. In the two specimens dissected there are six pairs of nephridia opening on the fourth to the ninth segments. The first nephridium is small, and its nephrostome is on the anterior face of the third diaphragm. The edge of the ventral lip of the larger nephrostomes is thrown into numerous folds or frills, as figured (see fig. 17). The vascular system agrees exactly with that of the Otago specimens.

There are multiple œsophageal glands to the number of twelve or thirteen on each side, the anterior ones digitiform or club-shaped, the others pyriform or ovoid. There are no pouches on the first diaphragm.

The only feature of an unusual character in the body of the animal is the presence of a partial septum one segment behind the third diaphragm. This structure is homologous to the septa met with in the posterior branchial region of this and other Arenicolidae. It is a membrane supporting both the afferent and efferent vessels to the second pair of nephridia, and is nearly 3 mm. across in its widest part. It is not so extensive as the third diaphragm (which in the same specimen is over 6 mm. across), as it does not reach either the dorsal or the ventral body-wall. It may be regarded as merely an exaggeration of the supporting strands which are usually present in other species alongside either one or both of the vessels to the nephridia (see, for example, *A. grubii*, Gamble and Ashworth, 1900, pl. xxvi, figs. 53, 54).

The two specimens examined are females which have probably spawned, as only a very few ova are present in the

¹ In one specimen the true first gill is absent on the right side.

body-cavity. These are large, and measure across their flat faces 0.2×0.17 mm. (see pp. 747 and 758).

The anterior end of one of the specimens was cut into sections. A pair of large otocysts is present (fig. 14). They are much larger than those of the Otago specimens and a little larger than those of the worms from *Uschuaia* (cf. figs. 13, 14, 15). Their three diameters are respectively about 0.36, 0.38, and 0.28 mm. (compare the measurements on pp. 752 and 759).

The otoliths are all spherical or nearly so, and are composed of a yellowish or brownish secreted substance. There are in each otocyst two otoliths (fig. 14) considerably larger than the rest. They are about 0.055 mm. in diameter, and in the centre of each is a small irregular foreign body, probably a quartz-grain. The smaller otoliths are usually from 0.02 to 0.03 mm. in diameter, and only rarely is a foreign particle visible in them, though doubtless each has a very minute central nucleus of this description. The two large otoliths described above are probably the first otoliths of the post-larval stage, which always remain distinguished by their greater size from those which are formed later. A similar condition exists in *A. ecaudata*, in the post-larval stage of which there is for some time only one otolith, which always remains conspicuous, owing to its larger size (Gamble and Ashworth, 1900, p. 504 and fig. 64).

The otocyst opens to the exterior by a tube, the external opening of which corresponds in position to that of the Otago specimens and of *A. marina*. The lumen of the tube is of moderate size along the greater part of its length, but is reduced near its entrance to the otocyst in one case to a very narrow passage, and in the other is practically obliterated. The wall of the tube is remarkable for the presence of large gland-cells, which are practically confined to the dorsal wall. They are almost ovoid in shape, and their cell-contents are in the form of a reticulum. In the ventral wall of the tube there are numerous elongate fusiform sense cells.

The remaining structures shown in sections of the anterior

end are so exactly similar to those of the Otago specimens that no further description of them is necessary.

The specimens above described are interesting from their bearing on the discussion regarding the taxonomic value of the shape of otoliths (see p. 761). The only difference between the Falklands specimen and those from New Zealand is that in the former the otoliths are spherical and composed almost entirely of a secreted substance, while in the latter they consist of irregular foreign bodies, such as sand-grains and fragments of spicules. There can be no doubt that the two sets of specimens belong to the same species, or rather to the same variety, so that (as was also proved for *A. marina*, see p. 762) the shape of the otoliths varies in different specimens of the same species or variety. The closure of the tube of the otocyst along part of its length and the presence of the numerous large gland-cells in its wall are probably the principal factors in determining the shape and nature of the otoliths of the Falklands specimens. Having proved the presence of spherical otoliths in some examples of *A. assimilis*, var. *affinis*, it will be noticed that one of the differences (discussed on pp. 761—763) between this new variety and the type of the species disappears; so that now the only features by which they may be distinguished are (1) the presence of twenty chaetigerous segments in the type of the species, whereas the new variety possesses only nineteen, and (2) the slightly different position of the external opening of the otocyst. As the latter is too fine a character for ready application in systematic work, it may be said that the determination rests upon the number of chaetigerous segments.

Another striking feature about the otocysts is the great difference in their size in specimens of the variety from the two localities. Whereas in the Otago specimens their average diameter is 0.21 mm. (in a specimen 136 mm. long), in one (128 mm. long) from the Falklands their average diameter is 0.34 mm. (cf. figs. 14, 15), so that the internal volume of the latter is about four times that of the former.

Adult specimens of the new variety are now recorded from

the same locality as the post-larval stages described on pp. 764—768. There can be no doubt that the latter are stages in development of the former. Judging from Ehlers' record (1897, p. 104) of the capture near Uschuaia of a gill-less specimen 6.5 mm. long with nineteen chaetigerous segments, it seems probable that the variety occurs at this place along with typical specimens of the species.

VII. Distribution of *Arenicola assimilis*.

Ehlers (1901, p. 178) records the occurrence of *A. assimilis* in collections from the Straits of Magellan (Punta Arenas and Susanna Cove), the Beagle Channel (Uschuaia and Lapataia Nueva), South Georgia, Chile (Schmarda), Kerguelen (Grube), and California.

Schmarda's (1861, pp. 51, 52) *A. piscatorum* from Chile and Grube's (1878, pp. 511, 554) *A. piscatorum*, Cuv., var., from Kerguelen, are both included by Ehlers under the species *A. assimilis*. Although Schmarda gives a brief description of some points in the anatomy of his specimens he unfortunately does not mention any characters which enable their identity to be definitely settled. With respect to Grube's specimen from Kerguelen the only information given is that most of the branchiferous segments are divided into only four annuli, and owing to this feature Grube distinguished his specimens as a variety of *A. piscatorum*. There is no evidence to show that any of these specimens belong to the species *A. assimilis*.

Ehlers (1897, p. 104) states that in the Göttingen collection there is a species of *Arenicola*¹ from California in which there are twelve pairs of gills which agree in position with those of *A. assimilis*, and these specimens are dis-

¹ I thank Professor Ehlers for sending to me by letter the further information that this is a duplicate from Professor Agassiz's collection, which was sent to Göttingen to be worked over. The rest of the specimens were returned to Professor Agassiz, and are doubtless those referred to on the next page.

tinguishable from *A. marina* only by this character. No mention is made of other features which would have been much more valuable as diagnostic characters, but the difference in the number of gills is accepted as a sufficient ground for separating the specimens from *A. marina*, notwithstanding the well-known liability to reduction (from thirteen to twelve pairs) in the number of branchiae in this species. As will be seen from the discussion below, it is very probable that Ehlers' specimen does not belong to either of these species, and that this is an example of the confusion due to placing an implicit reliance on the value of external features in discriminating species of *Arenicola*. On such a variable and insufficient character as the number of gills Ehlers bases his diagnosis of the Californian specimen, and refers it to the species *A. assimilis*. This is the only evidence in support of his record of this species from California.

I have recently re-examined specimens of *Arenicola* from a collection made by Professor Agassiz, near Crescent City, California, sent to Dr. Gamble and myself from the Harvard Museum, and identified by us (1900, p. 423) as *A. claparedii*. These specimens are the more interesting because they are accompanied by a label¹ indicating that they have passed through the hands of Professor Ehlers, and that he considered them to belong to a new species nearly related to *A. marina* (= *piscatorum*). It is almost certain that these are the same specimens which Ehlers has recorded as *A. assimilis*. There are five specimens, in three of which there are twelve pairs of gills, the first situated on the eighth chætigerous segment. In each of the other two specimens there are twelve gills on the left side (the first being on the eighth segment), accompanied in one case by thirteen gills on the right, the first being very small and borne on the seventh segment, while on the right side of the other

¹ The writing upon the label, which is now faint, is as follows:—
“*Arenicola*, n. sp. nahe *piscator*. 7 vor Segm. 12(13) Kiementrag.
Californien (E. Ehlers).”

specimen there are only eleven gills, the first of which is on the ninth segment. It may therefore be said that it is usual to find the first gill in these specimens on the eighth segment as in *A. assimilis*. Dissections of two of the specimens show that there are five pairs of nephridia, multiple oesophageal glands, and no pouches on the first diaphragm; and sections of the anterior end prove conclusively that there are no otocysts. All these points are so characteristic of *A. claparedii* that there can be no doubt that the specimens belong to this species.

I am indebted to Dr. H. P. Johnson for two specimens of *Arenicola* from Puget Sound, Washington. In one of these¹ there are thirteen pairs of gills, but in the other the seventh segment bears a gill only on the right side, the first left gill being on the following segment. Dissections of the specimens and sections of the anterior end of one of them fully confirm the determination of their species made by Dr. Johnson (1901, p. 421); they are undoubted *A. claparedii*.

It is therefore highly probable that Ehlers is in error in recording *A. assimilis* from California. In the first place, his determination of the species of the Californian specimens rests solely upon a character which is very variable and almost useless for distinguishing species; secondly, a re-examination of what are probably the very same specimens proves them to be *A. claparedii*, and this species has been recorded from another point on the west coast of the United States.

A revision of Ehlers' record of the distribution of *A. assimilis* therefore becomes necessary, and may be given as follows:—Adult typical specimens of *A. assimilis* have been recorded from several places in the extreme south of the

¹ It is remarkable that of the seven specimens examined from the west coast of the United States this is the only one which possesses the full number of gills. On the contrary, it is unusual to find any departure from the normal number in Neapolitan specimens of *A. claparedii*; out of thirty-nine examined only two show a reduction in the number of gills; in each case there are thirteen on the left side, but only twelve on the right.

American continent and from South Georgia. Others forming a new variety but agreeing with the type, except in the number of chætigerous segments, are now recorded from Otago Harbour, the Macquarie Islands, and the Falkland Islands. Post-larval stages of the variety have been obtained off Stanley Harbour (East Falkland) and near Uschuaia.

VIII. Specific Characters of the Caudate Arenicolidæ.

Appended is a revised summary of the characters of the caudate Arenicolidæ, which clearly shows by what features, both external and internal, *A. assimilis* may be readily recognised and distinguished from other species with which it is liable to be confused. It cannot be too strongly urged that attention should be directed by systematists chiefly to internal characters in the discrimination of the species of *Arenicola*. No determination of *A. marina*, *A. claparedii*, or *A. assimilis* can be considered complete or entirely trustworthy which relies solely on external characters. It is impossible to distinguish these three species with certainty unless reference be made to the nephridia, œsophageal glands, and otocysts, the two former being of especial use in this connection.

The characters¹ of the caudate Arenicolidæ may be briefly stated thus:

A distinct tail present; the parapodia and gills do not extend to the posterior end of the animal. The body is often swollen anteriorly. Gills, pinnate or derivable from the pinnate type, eleven to thirteen pairs, the first (which may be small or even absent) on the seventh or eighth chætigerous segment. Prostomium consisting of a median and two lateral lobes. Nephrostomes with dorsal lip well provided with flattened, spatulate, ciliated, vascular processes;

¹ The following is a revision of a part of the summary published by Dr. Gamble and myself (1900, p. 510), to which reference may be made for the characters of the genus and of the ecaudate species.

ventral lip ciliated, entire (i. e. not deeply notched as in the ecaudate Arenicolidae). Gonads small, ova discoidal.

(a) *A. marina*, Linn.—Nineteen chaetigerous segments. Thirteen pairs of gills; the first, which is on the seventh segment, may be reduced (or suppressed). Otocysts opening to the exterior. Otoliths, numerous foreign bodies (quartz-grains, etc.), which may, however, be covered with a layer of secreted chitinoid substance, giving them a rounded outline. Six pairs of nephridia opening on segments 4 to 9. One pair of œsophageal pouches, cylindrical, club-shaped, or conical. Diaphragmatic pouches (on the first diaphragm) small, globular, or flask-shaped.

Found on both sides of the North Atlantic.

(b) *A. assimilis*, Ehlers.—Twenty chaetigerous segments. Thirteen pairs of gills, the first of which is situated on the eighth segment (the first gill is liable to be reduced or suppressed). Otocysts large, opening to the exterior. Otoliths numerous; spherical or rounded chitinoid bodies. Six pairs of nephridia opening on segments 4 to 9. Several pairs of œsophageal pouches; the anterior pair long, club-shaped, or filiform; the others much smaller and pear-shaped. No pouches on the first diaphragm.

Recorded from the extreme south of the American continent.

(c) *A. assimilis*, var. *affinis*, Ashworth.—Nineteen chaetigerous segments. Thirteen pairs of gills, the first (liable to reduction or suppression) on the seventh segment. Otocysts large, opening to the exterior. Otoliths numerous, and composed either of foreign bodies (quartz-grains, etc.) or of spherical chitinoid bodies. Other characters as in the type of the species (see above).

Recorded from Otago Harbour, New Zealand, the Macquarie Islands, the Falkland Islands.

(d) *A. claparedii*, Levinsen.—Nineteen chaetigerous segments. Thirteen pairs of gills, the first on the seventh segment (this pair of gills is liable to reduction or suppression, especially in specimens from the west coast of North

America). Lateral lobes of prostomium well developed. No otocysts. Five pairs of nephridia opening on segments 5 to 9. Two or more pairs of œsophageal pouches, the anterior pair long and slender or club-shaped, the others shorter, usually pyriform. No pouches on the first diaphragm.

Recorded from the Mediterranean and from the west coast of the United States.

(e) *A. cristata*, Stimpson.—Seventeen chaetigerous segments. Eleven pairs of gills, the first on the seventh segment. Otocysts, closed spherical sacs each containing a single large, spherical, chitinous otolith. Six pairs of nephridia opening on segments 5 to 10. One pair of œsophageal pouches cylindrical or club-shaped. Diaphragmatic pouches (on the first diaphragm) large and finger-shaped.

Found in the Mediterranean, in the West Indies, and on the eastern shores of North America south of latitude 40° N.

IX. Summary of Results.

1. The anatomy of *Arenicola assimilis* is fully described for the first time. Although Ehlers states that the species differs from *A. marina* only in the number of chaetigerous segments (nineteen in the latter, twenty in the former), in the position of the first gill and in the relative size of the middle lobe of the prostomium, further examination shows that there are other important points of difference, e. g. *A. assimilis* possesses multiple œsophageal glands and has no pouches on the first diaphragm.

2. Specimens of *Arenicola* are described from Otago Harbour (New Zealand) and from the Macquarie Islands which differ from the type in the number of chaetigerous segments (nineteen) and situation of the first gill. There is also a difference in the shape of the otoliths; in the type they are spherical or rounded, while in the New Zealand specimens they are irregular. These specimens belong to a new variety (var. *affinis*) of the species.

3. In the discussion of the systematic position of the Otago specimens it is concluded that the form of the otoliths is not sufficiently reliable to form a character by which species may be discriminated. In *A. marina* the otoliths are usually irregular, but two out of nine specimens examined possess rounded otoliths. In these cases the otoliths were at first irregular foreign bodies, but they have been covered with layer upon layer of secreted substance, and now have a rounded outline. In each of these two cases the tube which placed the otocyst in communication with the exterior has become either wholly or partially blocked, either by apposition of its walls or by the secretion into the lumen of a glandular substance which forms an effectual plug. In the seven specimens of *A. marina* with irregular otoliths the tubes are not closed in this way. It is concluded that the presence of spherical or rounded otoliths is associated with the closure of the tube, and it is pointed out in support of this conclusion that the other species (*cristata*, *grubii*, and *ecaudata*) in which spherical otoliths are found have closed otocysts (pp. 761—763).

4. The brain is well developed. The ganglion-cells of its middle region are large (especially in the Otago specimens) and send processes into the neuropile, where they branch freely.

5. Giant-fibres and segmentally arranged giant-cells are present in the nerve-cord. They have the same structure as in *A. grubii*.

6. The otocysts of *A. assimilis* are distinguished by their size. They are considerably larger than those of any other species. Neuro-fibrillæ may be traced from the nervous sheath of the otocyst into and along the whole length of the sense cells of the otocystic epithelium. These cells and fibrils are especially abundant near the point of entrance of the tube to the otocyst.

7. There is a large nerve-supply to the skin and proboscis. Neuro-fibrillæ may be seen in some of the cells of the general body-surface and of the papillæ of the proboscis.

8. Post-larval specimens of *A. assimilis*, var. *affinis*, are described from the Falkland Islands. They possess an achæton segment between the peristomium and first chaetigerous segment (as in similar stages of *A. marina* and *A. ecaudata*). By comparison with the adult the limits in the latter of the peristomium and achæton body-segment may be determined (figs. 19, 20).

9. Adult specimens of *A. assimilis*, var. *affinis* are also described from Stanley Harbour, East Falkland. They are remarkable for the large size of their otocysts, the internal volume of which is about four times that of the otocysts of the Otago specimens (figs. 14, 15). It is evident that a considerable variation in the size of these organs may occur in specimens of the same species or variety from different localities. The otoliths, several of which contain an irregular foreign body, are spherical, and in one specimen two of them are much larger than any of the others. They are the first two otoliths of the post-larval stage which have continually received fresh depositions of secreted substance, and always remain distinguished from those formed later by their larger size. These specimens from the Falklands differ from the Otago specimens in the nature of their otoliths. Here is additional evidence that the character of the otoliths contained in otocysts provided with a tube leading to the exterior is not a feature upon which much value should be placed in systematic work. Blocking of the tube (as occurs in the Falklands specimen) converts the otocyst into a closed sac, in which spherical otoliths are formed, while in other specimens (e. g. those from Otago Harbour) in which the tube remains open the otoliths are irregular foreign bodies, such as sand-grains, which are able to gain access to the otocyst.

10. Ehlers records *A. assimilis* from the Straits of Magellan, the Beagle Channel, South Georgia, Chile (Schmarda), Kerguelen (Grube), and California. It is shown that there is no evidence in support of the last three records. Schmarda's and Grube's specimens are insufficiently

described, and no character is mentioned by which their species may be determined. Ehlers' diagnosis of the Californian worms rests solely upon a character which is very variable and almost useless for distinguishing species. A re-examination of what are probably the same specimens proves them to be *A. claparedii*, and this species has also been recorded from another point on the west coast of the United States (pp. 772—774). Incidentally it may be mentioned that specimens of *A. claparedii* from the west coast of North America almost invariably bear only twelve gills either on one or both sides, while Neapolitan specimens have usually the full number (thirteen pairs).

A. assimilis may be regarded as the characteristically southern species of the genus. Adult typical specimens are recorded from several points in the extreme south of America and from South Georgia. A new variety (var. *affinis*), differing from the type only in the number of chætigerous segments, is now recorded from Otago Harbour (New Zealand), the Macquarie Islands, and the Falkland Islands. Post-larval stages of the variety have been taken off the Falklands and near Uschnaia, in the Beagle Channel.

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EXPLANATION OF PLATES 36 & 37,

Illustrating Dr. J. H. Ashworth’s memoir on “The Anatomy of *Arenicola assimilis*, Ehlers, and of a New Variety of the Species, with some Observations on the Post-larval Stages.

LIST OF REFERENCE LETTERS.

A. B. S. Achæitous segment of body between peristomium and first chaetigerous segment. *Ant. Cer. L.* Anterior lobe of brain. *Bl.* Bladder of nephridium. *B. V.* Blood-vessel. *C.* Cuticle. *Ch. Seg. 1* First chaetigerous segment. *Coel.* Coelom. *Conn. Tiss.* Connective tissue. *Epid.* Epidermis. *E. T.* Entrance to tube leading from otocyst to exterior. *Ext. Op. Ot.* External opening of otocyst. *Gang. C.* Ganglion-cell. *Gast. Lat.* Lateral gastric vessel. *Gl. C.* Gland cell. *Gon.* Gonad. *Gon. V.* Gonidial vessel. *Ht.* Heart. *Met. Gr.* Metastomial groove. *Middle Comm.* Middle commissure of brain. *M. Circ.* Circular muscles. *M. Long.* Longitudinal muscles. *Mo.* Mouth. *M. Sh. Bucc.* Muscular sheath of buccal mass. *N.* Band of nerve-fibres from prostomial epithelium to brain. *N. Aff.* Afferent vessel of nephridium. *N. Bucc.* Nerve to buccal mass and papillæ of “proboscis.” *N. C.* Nerve-cord. *N. Epid.* Nerve to epidermis. *Nm. Ch.* Neuropodial chaetæ. *Not. S.* Notopodial setæ. *Nphm. D.* Dorsal lip of nephrostome. *Nphm. V.* Ventral lip of nephrostome. *Npile.* Neuropile. *Nuc. Gr.* Nuchal groove. *Oc.* Eye. *Œ.* Œsophagus. *Œ. Conn.* Œsophageal connective. *Œ. Gl.* Œsophageal gland. *Ot.* Otocyst. *Oth.* Otolith. *Ol. T.* Tube of otocyst. *Pap.* Papilla of “proboscis.” *Per.* Peristomium. *Ph.* Pharynx. *Post. Cer. L.* Posterior lobe of brain. *Prost.* Prostomium. *Prost. Epith.* Epithelium of prostomium. *Prost. Lat.* Lateral lobe of prostomium.

Prost. Mid. Middle lobe of prostomium. *Sp.* Fragment of spicule. *St.* Stomach. *V. V.* Ventral vessel.

PLATE 36.

FIG. 1.—Distal half of a seta from the fifth notopodium of a specimen of *Arenicola assimilis* from Uschnaia. $\times 100$.

FIG. 1 A.—A portion of the seta more highly magnified. Note the lamina on the left bearing fine teeth. $\times 750$.

FIG. 2.—Distal portion (two fifths) of a seta from the sixth notopodium of a specimen of *A. assimilis*, var. *affinis*, from Otago Harbour. $\times 100$.

FIG. 2 A.—A portion of the same seta more highly magnified. Note the broad lamina crossed by fine oblique lines. $\times 500$.

FIGS. 3, 4, 5.—Notopodial setæ from a post-larval specimen (7.6 mm. long) of *A. assimilis*, var. *affinis*. Most of the setæ are of the kind shown in Fig. 3, but in each notopodium there is one seta of the type seen in Fig. 5. Setæ of the kind shown in Fig. 4 are much less common than the preceding; only two specimens were seen in ten notopodia. The lamina is breaking up on one side near its tip into fine teeth. $\times 320$.

FIG. 6.—Tip of a seta of the same kind as shown in Fig. 5. Note the fine teeth on the margin of the lamina on one side. $\times 600$.

FIG. 7.—A crotchet from the fifteenth neuropodium of an Otago specimen (var. *affinis*). $\times 100$.

FIG. 8.—The head of a crotchet from another Otago specimen, to show the teeth situated on the sides of the rostrum. $\times 280$.

FIG. 9.—A crotchet from the fifteenth neuropodium of *A. assimilis* from Uschnaia. $\times 100$.

FIG. 10.—Two crotchets from the sixteenth neuropodium of a post-larval specimen (7.6 mm. long) of *A. assimilis*, var. *affinis*. *A* shows the appearance of the chaeta when the rostrum and post-rostral teeth are in focus; in *B* the teeth on the sides of the rostrum are also shown. The subrostral process is now seen to be one of the series of teeth. The dotted line indicates the level of the epidermis. $\times 600$.

FIG. 11.—Diagram of a portion of the nerve-cord of *A. assimilis*, var. *affinis*, from Otago Harbour, to show the distribution of the giant nerve-cells. The transverse lines indicate the position of the neuropodia, the numbers of which they bear. The nerve-cord is magnified about 10 times and the cells 40 times.

FIG. 12.—Diagram of a portion of the nerve-cord of *A. assimilis* from Uschnaia, to show the distribution of the giant nerve-cells. The transverse lines indicate the position of the neuropodia. The last giant-cell shown

situated (probably) in the first tail segment. The nerve-cord is magnified about 10 times and the cells 40 times.

FIG. 13.—Shows the size of the otocyst of a specimen (120 mm. long) of *A. assimilis* from Uschuaia. The oval outline is a camera drawing of the cuticle which lines the otocyst. The tube which leads from the exterior enters the otocyst near the point marked *E. T.* The otoliths are rounded, and many of them show concentric markings, indicating their deposition in layers. In the centre of several of them small foreign bodies may be distinguished. Attached to some of the otoliths are other small rounded bodies of a similar nature, but which stain more deeply. The minute deeply staining spherules (indicated by the dots) are also composed of a similar substance. $\times 210$. (Cf. Figs. 14, 15.)

FIG. 14.—Camera drawing of the cuticle lining the otocyst of a specimen (128 mm. long) of *A. assimilis*, var. *affinis*, from the Falkland Islands. The otocyst is somewhat larger than the one shown in Fig. 13. The otoliths are nearly spherical. (They are not all present in one section; some are added from another section.) The two larger ones are probably the first otoliths of the post-larva, which are easily distinguished by their size from those which are formed later. In the centre of each of the large otoliths an irregular foreign body may be seen. $\times 210$. (Cf. Figs. 13, 15.)

FIG. 15.—Camera drawing of the cuticle lining the otocyst of a specimen (136 mm. long) of *A. assimilis*, var. *affinis*, from Otago Harbour. The otocyst is much smaller than either of the two preceding. The otoliths are irregular bodies, chiefly quartz-grains, but two small fragments of spicules (*Sp.*) are seen lying close together. $\times 210$. (Cf. Figs. 13, 14.)

FIG. 16.—Camera drawing of the cuticle lining the otocyst of *A. marina* (about 10 inches long). The tube connecting this otocyst to the exterior is almost blocked, and in consequence the otoliths, which were originally small irregular foreign particles, are now assuming a rounded outline, due to the deposition upon them of layer upon layer of secreted substance; see, for example, the otolith containing the spicule fragment (*Sp.*). Note the small size of the otocyst compared to those shown in Figs. 13, 14, and 15. $\times 210$.

FIG. 17.—Fifth nephridium of *A. assimilis* (specimen from Punta Arenas). The dorsal lip of the nephrostome (*Nphm. D.*) bears the usual ciliated vascular processes, while the edge of the ventral lip (*Nphm. V.*) is thrown into numerous folds or frills. Note the gonad, a somewhat club-shaped mass of cells around the gonidial vessel (seen by transparency through the gonad). $\times 10$.

FIG. 18.—Left aspect of the anterior portion of a post-larval specimen of *A. assimilis*, var. *affinis*, from the Falkland Islands. The total length of this specimen is 11.1 mm. Note the four cup-shaped eyes on the prostomium. Between the prostomium and the first chætigerous segment is a region

imperfectly divided into two by a groove; the anterior part—the peristomium (*Per.*)—is again partially subdivided into two annuli, in the anterior of which the otocyst (*Ot.*) may be faintly seen; the posterior part (*A. B. S.*) is the first body-segment, which, however, does not bear any traces of setæ. The succeeding segments bear notopodial and neuropodial setæ. The former usually consist of two or three capilliform bristles and one lanceolate seta (see also Figs. 3—6). The alimentary canal is seen by transparency through the body-wall. The buccal mass leads into the œsophagus, which dilates in the fourth chætigerous segment, and in the sixth bears the glands (*Æ. Gl.*), seven of which may be recognized. Immediately behind this the œsophagus is contracted, and leads into the stomach, on whose surface the almost rectangular chlorogogenous areas are already differentiated. The nephridiopores are not shown, as they are too minute to be detected with certainty. $\times 50$.

FIG. 19.—The anterior end of the same specimen. Ventral aspect. The slit-like cœlomic cavity between the two anterior brain-lobes is seen by transparency in the prostomium. The metastomial field—the area included between the œsophageal connectives—is slightly raised above the level of the general epidermis. The specimen shows the peristomium (*Per.*), the achæitous body-segment (*A. B. S.*), and the first chætigerous segment (*Ch. Seg.*). See description of previous figure. Compare these parts with those of the adult shown in Fig. 20. $\times 50$.

FIG. 20.—The anterior end of an adult specimen of *A. assimilis*, var. *affinis*, from Otago Harbour. Dorsal aspect. Note the prostomium with its V-shaped lateral lobes embracing the median one. The nuchal groove (*Nuc. Gr.*) and the origin of the metastomial groove (*Met. Gr.*) are shown. The first chætigerous segment (*Ch. Seg.*) consists of three annuli. The region between this and the prostomium is divisible into two almost equal parts, an anterior part—the peristomium (*Per.*)—in which the two annuli are not very regular, and a posterior part, consisting of two annuli, which form the achæitous body-segment (*A. B. S.*). $\times 8$. (Cf. Fig. 19.) The form of the prostomium and the annulation of the skin of type specimens of *A. assimilis* from *Usehuaia* are exactly the same as shown in this figure.

FIG. 21.—Transverse section of a post-larval specimen of *A. assimilis* var. *affinis*, 8.7 mm. long. The section passes somewhat obliquely through the posterior brain-lobes, the nuchal organ, and the otocyst of the right side. The two posterior cerebral lobes (*Post. Cer. L.*) are seen in the prostomium separated by a portion of the cœlomic cavity. They are closely applied to the nuchal organ, the ciliated epithelium of which is well seen on the left, but is cut obliquely on the right. The right otocyst is seen as an invagination of the epidermis, the mouth of the pit being narrowed to form the tube of the otocyst. Already a few foreign bodies (otoliths) have gained admittance. Note the large gland-cells scattered in the epithelium, the sections of the

œsophageal connectives, the pharynx, the circular and longitudinal muscles. The nuclei of the muscle-fibres have been omitted. $\times 210$.

PLATE 37.

FIG. 22.—Transverse section of the anterior end of a specimen of *A. assimilis*, from Uchuia. The section passes through the anterior part of the brain at the point of origin of the œsophageal connectives. The two anterior cerebral lobes are seen in the prostomium in close relation to its epithelium; bands of nerve-fibres (*N.*) may be seen passing from the latter into the brain. The cells in the brain are represented by the dots shown in the figure. The spaces seen in the brain and in the subepidermal tissue are canaliform prolongations of the cœlomic cavity. On the left the section has passed somewhat obliquely through the skin, and shows the numerous branches given off from the œsophageal connective, and ending in the basal part of the epidermis. The dots in these nerves represent the nerve-cells which are present. Immediately to the left of the prostomium is the external opening of the otocyst (*Ext. Op. Ot.*), the tube being cut through along a considerable part of its length; a transverse section of the inner part of the tube is seen just ventral to this. In the lower part of the figure the buccal mass is seen cut across; the elevations of the epithelium (*Pap.*) shown are the papillæ of the "proboscis." The nerves (*N. Bucc.*) which supply these are shown. Note the strong musculature of the buccal mass. $\times 30$.

FIG. 23.—Transverse section of the middle portion of the brain of a specimen of *A. assimilis* var. *affinis*, from Otago Harbour. Only the left half of the section is drawn; the median plane is indicated by the two vertical lines. In the upper part of the section the intimate relation of the prostomial epithelium and the brain may be observed; the ganglion-cells extend up to, and lie among the bases of, the epithelial cells. The dots in the brain represent the nuclei of small nerve-cells, which are usually arranged in groups or clusters. The large cells in the middle of the figure show the form and position of the larger ganglion-cells of the brain. Their processes extend downwards into the neuropile, where they branch. Note the numerous fibres passing from the left half of the brain across the middle line to the right, forming the middle cerebral commissure. The isolated cell on the right side is drawn from another section. $\times 210$.